ECONOMY AND ENVIRONMENT PROGRAM FOR SOUTHEAST ASIA

Tradable Discharge Permits System for Water Pollution of the Upper Nanpan River, China

Wendong Tao, Weimin Yang & Bo Zhou

EEPSEA RESEARCH REPORT SERIES

EEPSEA is supported by a consortium of donors and administered by IDRC.
Mailing Address: Tanglin PO Box 101, Singapore 912404
Visiting Address: 7th Storey RELC Building, 30 Orange Grove Road
Telephone: 65 235 1344 Fax: 65 235 1849
Internet: dglover@idrc.org.sg or hermi@laguna.net
Website: http://www.idrc.org.sg/eepsea

Comments should be sent to the authors at Yunnan Institute of Environmental Sciences or at Yunnan Environmental Protection Bureau, 23 Wang Jia Ba Kunming 650034, CHINA. E-mail: wtao@public.km.yn.cn or ftecd@public.km.yn.cn

The Economy and Environment Program for South East Asia (EEPSEA) was established in May, 1993 to support research and training in environmental and resource economics. Its objective is to enhance local capacity to undertake the economic analysis of environmental problems and policies. It uses a local networking approach, involving courses, meetings, technical support, access to literature and opportunities for comparative research. Member countries are Thailand, Malaysia, Indonesia, the Philippines, Vietnam, Cambodia, Laos, China, PNG and Sri Lanka.

EEPSEA's funding is provided by a consortium of donors. As of June 1998, these sponsors consisted of IDRC (Canada), Sida (Sweden), Danida (Denmark), the Ministries of Foreign Affairs of Norway and the Netherlands and the MacArthur Foundation (USA).

EEPSEA Research Reports are the outputs of research projects supported by EEPSEA. They have been peer reviewed and edited. In some cases, longer versions are available from the authors. EEPSEA also issues a Special Papers Series, consisting of commissioned papers emphasizing research methodology.

EEPSEA is supported by a consortium of donors and administered by IDRC.

Mailing Address: Tanglin PO Box 101, Singapore 912404 ● Visiting Address: 7th Storey RELC Building, 30 Orange Grove Road ● Telephone: 65 235 1344 ● Fax: 65 235 1849 ● Internet: dglover@idrc.org.sg or hermi@laguna.net ● Website: http://www.idrc.org.sg/eepsea

ECONOMY AND ENVIRONMENT PROGRAM
FOR SOUTHEAST ASIA

Tradable Discharge Permits System for Water Pollution of the Upper Nanpan River, China

Wendong Tao, Weimin Yang & Bo Zhou

January 1998

This work was carried out with the aid of a small grant from EEPSEA. We wish to acknowledge the contributions of Dr. William F. Barron who provided continuous comments and suggestions. Our thanks also to Dr. David James, Dr. John Whalley, Dr. David Glover and Dr. Herminia Francisco, and to the many EEPSEA workshop participants for their useful comments and suggestions. We would like to thank the US EPA Region 5, NSW EPA of Australia and David James for providing valuable materials.

TABLE OF CONTENTS

List of Tables and Figures

Appendices

Tradable Discharge Permits System for Water Pollution of the Upper Nanpan River, China

Wendong Tao[1], Weimin Yang[2] and Bo Zhou[3]

EXECUTIVE SUMMARY

The upper Nanpan river in Qujing city, Yunnan province, China is heavily polluted. Its main stream (122 km long) is designated as water for industrial and agricultural use. However, the instream water quality is unsuitable for any use. Industrial discharges and municipal sources contribute significantly to the river's pollutant loads which are much higher than the total maximum loads allowable (TMLAs).

Substantial efforts have been made to correct the situation, but the water pollution is still out of control. At present, it appears that environmental management instruments must be improved, and more capital must be invested in water pollution control. Among several environmental management instruments implemented in the upper Nanpan river catchment area, the current non-tradable permits system for water pollution must be improved first through the development of a tradable discharge permits (TDP) system for water pollution. By providing flexibility to the dischargers, the trading system is assumed to be more cost-effective in attaining specific effluent reduction targets than the non-trading system.

This report provides information on and analysis of point/point source effluent trading, an explanation of the theory underlying trading, an examination of international experiences to date, and an evaluation of the lessons learned. It also focuses on evaluating the applicability of a practical TDP system to the upper Nanpan river. With regard to the necessary conditions for point/point source trading, the catchment appears good. Since the trading program is developed on the basis of the current non-tradable permits system for water pollution, the catchment generally meets eight of the nine conditions:

- The water body is an identifiable river segment.
- Point sources contribute significantly to the river water pollution. At present, there are sufficient, diverse point sources.
- The TMLAs have been established under the current permits system and modified.
- Accurate and sufficient data on wastewater characteristics of major dischargers have been accumulated to develop pollution reduction options. However, a computer information system should be set up to update and take full advantage of the continuously changing data/information.

1 Senior Engineer and Director, Plateau Lake Lab, Yunnan Istitute of Environmental Sciences, 23 Wang Jia Ba Kunming 650034, CHINA
2 Senior Engineer and Director, Yunnan Istitute of Environmental Sciences, 23 Wang Jia Ba Kunming 650034, CHINA
3 Project Officer, FTECD, Yunnan Environmental Protection Bureau, 23 Wang Jia Ba Kunming 650034, CHINA

- The concentration-based discharge requirements must, at a minimum, be met by all the industrial dischargers.

- The combination of the large remaining reduction requirements and the differential of unit costs of pollution reduction makes a large difference in pollution reduction costs across dischargers, consequently providing incentives for trading.

- The regulatory agencies support TDP and the dischargers do not oppose permit trading.

- There is an appropriate institutional structure for management of the trading program.

- Sufficient and effective compliance incentives and enforcement mechanisms need to be developed.

A point/point source trading system for chemical oxygen demand (COD) and 5-day biochemical oxygen demand (BOD_5) discharge is proposed for the upper Nanpan river, with participants covering both existing and new point sources in a smaller trading zone, the vicinity of Xiping town and the urban center. The main objective is to achieve the total reduction targets (TRTs) at a lower total cost than the non-tradable permits system by providing opportunities for point sources that would otherwise have to install high-cost technologies to pay for generally less expensive point source controls.

This project emphasizes economic analysis of COD discharges of the participants within the trading zone. Among the 18 industrial participants of the current permits system in the trading zone, 12 industrial dischargers and two main municipal sources are identified as potential participants of the trading program. The annual reduction cost, the sum of annualized capital cost and annual operation and maintenance (O&M) cost, is estimated and used to compare the cost-effectiveness of pollution reduction options. The first hand information sources consist of existing research reports, environmental impact statements, feasibility study reports, design specification, and permits application documents. The secondary information sources are government guidelines for best practical environmental protection technologies and cleaner production processes. While it would be better if there was direct cost information from dischargers, the sources used are relatively detailed and developed for the local conditions. Coefficients are used to make adjustments in the unit costs obtained from the secondary sources to fit to local conditions. The coefficients vary between 0.7 and 1.0, accounting for the specific site condition, design capacity, wastewater characteristics, and so on. Hence, it is felt that a reasonable approximation is provided for actual reduction costs for individual polluters involved in the study.

The trading opportunities are identified by comparing unit costs across all reduction options of the potential participants, with practical assumptions - the amount of allowance that could be traded should be large enough to install a certain unit treatment process; and few dischargers are assumed to solely seek financial gain by upgrading their treatment facilities and selling the excessive allowances. The potential benefit, direct reduction cost-savings, is the difference between the total cost if each discharger is required to achieve its permit limits by upgrading wastewater treatment facilities (WTFs) --without trading and the total cost if trading is allowed to be an alternative for the dischargers to achieve their permit limits --with trading. The results indicate that the municipal sources must be covered by the trading program; there was one case of trade between the industrial participants, several trades between the Qujing municipal source and industrial sources, and one case of trade between the two municipal sources. These trading cases would gain an annual cost-saving of CNY2.4 million (8.3 Chinese Yuan = 1 US dollar), or 18.4 percent of the total annual cost to attain the COD TRT without trading. The unit price of the last trade, that can be approximately considered the marginal pollution reduction cost of the upper Nanpan river catchment, is CNY959/ kg COD/day.

Another important finding is that the without trading and with trading options will, due to specific pollution control engineering, brings about 900.9 kg/day and 51.5 kg/ day of redundant reduction, respectively, beyond the required reduction. If the additional benefits associated with the without trading are considered, the net annual benefit arising from trading, CNY1.6 million, would still be significant.

Estimating the benefits of any TDP system is difficult before the system is actually in place. If BOD data were used to estimate the cost-saving, results could be different. The research intends to help the government and industry accept the TDP system through approximation of the benefits from trading rather than an exact estimation of benefits.

International experience related to the study has revealed a few other concerns important for implementing the TDP system: program design, reporting and monitoring requirements, institutional/administrative requirements, additional administrative and monitoring costs for trading, alternatives for initial allocation of permits, and social implications. Although these complex aspects would be addressed in depth at later stages, a few recommendations for elaborating the trading program are proposed:

- In program design, compliance monitoring and execution of institutional requirements must be considered. However, the program must be carefully designed to minimize administrative and transaction costs imposed on dischargers and regulatory agencies.

- The program design must be as simple as possible, at least for a pilot period, making provisions as explicit as feasible and minimizing the points of administrative intervention.

- Factors influencing participation, and consequently cost-savings, must be taken into account in trading program design. These factors include prevention of environmental 'hotspots', the probable monopolistic behavior of municipal sources that can inhibit trading by industrial dischargers, duration of permits, and initial wasteload allocation method.

- The program should be location specific, to consider existing market conditions, role of local government, and economic situation of the area.

- The management agency in charge of trading must have adequate statutory authority to allocate permits, reject trades that threaten local water quality, enforce compliance, and enact other permit provisions.

1.0 INTRODUCTION

Every five years, the Yunnan Provincial Government formulates a socio-economic development plan which includes sections on environment. The eighth Five-Year Plan (1991-1995) targeted its effort on preventing and controlling water pollution of two bodies of water: the Dianchi lake in the provincial capital of Kunming and the Nanpan river. As part of the provincial government's initial efforts for the Nanpan River, a plan completed in 1994 (YIES 1995) proposed a comprehensive water pollution control program that included the development of a TDP system. The ninth Five-Year Plan (1996-2000) also emphasized water pollution control for the river.

At the time of the research, no concrete plan to develop a TDP has yet been made. However, managers of the Qujing Municipal Environmental Protection Bureau (QMEPB) and the Yunnan Provincial Environmental Protection Bureau (YPEPB) expressed strong interest in establishing the TDP system. This research is aimed at a) disseminating the concept of TDP, b) evaluating the applicability of a point/point source trading system to the upper Nanpan river in Qujing city, c) estimating the cost savings of effluent trading relative to non-trading, and d) identifying the concerns to be addressed later during elaboration of the trading program. The main objective was to attain the same TMLAs as the current non-tradable system but at a lower cost.

The outputs of this research may serve as a technical basis for elaboration and design of a workable TDP system.

2.0 BACKGROUND

2.1 Surface Water Problems in the Upper Nanpan River Catchment

2.1.1 Hydrology and Water Quality

The Nanpan river runs for 677 km in China's Yunnan province. It is a tributary of the Pearl river which merges with the South China Sea. The upper Nanpan river is 122 km long with a drainage area of 2486 square kilometers, stretching across Qujing city of Yunnan province, China. The monsoon brings to the catchment a mean annual rainfall of 811 mm with 80 percent of the annual precipitation falling in the rainy season (May to October). The river flow is highly variable yearly and seasonally.

Based on the distribution of point pollution sources, the upper Nanpan river is divided into different subzones (YIES 1995):

Subzone 1: Upstream of Huashan reservoir dam; length = 27.6 km

Subzone 2: Huashan reservoir to Xiping town; length = 36.2 km

Subzone 3: Xiping town to Qujing urban center; length = 21.9 km

Subzone 4: Urban center to Yuezhou town; length = 16.3 km

Subzone 5: Yuezhou town to Xiangshui reservoir; length = 19.7 km

The mainstream is designated as water for industrial and agricultural uses that require Class IV water quality set by the Surface Water Quality Standard of the People's Republic of China (SWQS). The river water is heavily polluted, and OLGTPS (1993) has designated the water quality objective of the mainstream as Class IV by year 2000 and Class III by 2010.

Table 1. Designated Water Uses (effective before 2000)

Name of Water Body	Designated Water Use/ Quality Requirement	Current Uses
Mainstream of Nanpan River from dam of Huashan Reservoir to Xiangshui Reservoir	Industrial use/Class IV	Irrigation and industrial use
Huashan Reservoir	Potential source of drinking water/Class II	Irrigation and industrial use
Tributaries of Huashan Reservoir	Headwater/Class I	Irrigation

According to the SWQS, the water quality from Class V to I becomes better and the corresponding uses change as follows:

Class I - headwater and national nature reserve;
Class II - the first level protected area for the centralized drinking water source, waters for precious fish, and the spawning ground of fish and shrimps;
Class III - the second level protected area for the centralized drinking water source and waters for common fish and swimming;
Class IV - waters for general industrial supply and non-contact water recreation; and
Class V - waters for agricultural supply and waters as common scenery.

Source: YIES, 1995

Regular water quality monitoring is conducted at four instream sections sampled six times a year. Monitoring results in recent years (YIES 1995) indicated that the water quality was much worse than the use requirements of Class IV, and that COD, BOD_5 and ammonia nitrogen (NH_3-N) were the critical pollutants. The water quality of its mainstream could not meet the lowest limits (Class V) of the SWQS in terms of BOD_5, COD and NH_3-N, especially during low-flow seasons. In other words, the river water is not suitable for any use.

Table 2. Current Situation of Major Water Quality Parameters

Sampling Point	BOD5	COD	Dissolved oxygen	NH_3-N	Unionized ammonia
Huashan Reservoir-inlet					
Low Flow	0.9/I	2.2/II	8.4/I	0.32	0.011/I
Moderate Flow	1.6/I	1.2/I	7.9/I	0.11	0.002/I
High Flow	1.5/I	1.8/I	7.3/I	0.26	0.015/I
Huashan Reservoir-near the dam					
Low Flow	1.1/I	1.3/I	8.8/I	0.04	0.002/I
Moderate Flow	1.6/I	2.2/II	7.6/I	0.04	0.002/I
High Flow	1.1/I	1.4/I	6.9/I	0.10	0.008/I
Zhanyi Bridge					
Low Flow	20.6/>V	42.5/>V	1.6/>V	37.17	0.58/>V
Moderate Flow	8.7/V	10.3/>V	5.4/III	19.70	0.89/>V
High Flow	6.8/V	11.8/>V	2.7/V	17.06	0.59/>V
Yuezhou Bridge					
Low Flow	4.2/IV	5.9/III	5.5/III	15.17	0.46/>V
Moderate Flow	4.5/IV	4.6/III	6.2/II	7.18	0.36/>V
High Flow	2.3/I	9.8/V	4.4/IV	5.26	0.21/>V

Note: Concentration in mg/l in 1993; COD was analyzed using potassium permanganate method.

Source: YIES, 1995

2.1.2 Sources of Pollutants

About 30 state-owned industrial enterprises concentrate in four regions along the river - three towns (Huashan, Xiping, Yuezhou) and the urban center - which discharge a great amount of wastewater into the Nanpan river.

The main urban center in the study area, Qujing (population of 240 000), is the second largest city in Yunnan province. Municipal wastewater mainly originates from Xiping town and the urban center. The municipal wastewaters are directly discharged into the upper Nanpan river without treatment.

Many rural enterprises concentrated in the urban center of Qujing and in the vicinity of the three towns along the river. The majority of these fell into the categories of building material manufacturing, food processing, textile and papermaking. It was estimated that rural enterprises contributed about 26.1% of industrial COD load to the upper Nanpan River. The non-tradable permits system neglected their contributions to river water pollution. Fortunately, the State Council's Decision Concerning Several Issues in Environmental Protection, a circular released in September 1996, stressed that the small enterprises with indigenous production processes must be closed down before September 30, 1996. For example, the pulp and paper mills with annual output lower than 5000 tons pulp are at the top of the closure list. Since then, the polluting rural enterprises have been nearly phased out.

Table 3. Load Balance of the Catchment[1]

	Discharge ton/day	BOD_5 Load ton/yr	CODcr Load[3] ton/yr	NH_3-N Load ton/yr
Year 1993				
Municipal	52 396	2 875.0	7 187.5	718.8
Industrial	39 048	820.4	3 495.6	1 325.1
Nonpoint		777.0	4 143.0	135.0
Subsum		4 472.4	14 826.1	2 178.9
Year 2000				
Municipal	77 987	5 069.1	10 137.5	854.1
Industrial	51 393	1 085.7	4 388.5	1 907.1
Nonpoint		777.0	4 143.0	135.0
Subsum		6 931.8	18 669.0	2 896.2
Year 2010				
Municipal	202 555	14 678.9	29 359.6	2 218.1
Industrial	62 233	1 189.1	4 742.6	1 976.2
Nonpoint		777.0	4 143.0	135.0
Subsum		16 645.0	38 245.2	4 329.3
Total Maximum Loads Allowable[2]				
By Year 2000		1 686.7	5536.7	878.5
By Year 2010		987.1	4113.4	84.3

1 Without consideration of the proposed Qujing Municipal Wastewater Treatment Plant.
2 Total maximum loads allowable, TMLA, are calculated at the mean lowest monthly instream flow.
3 Value analyzed using potassium dichromate method.

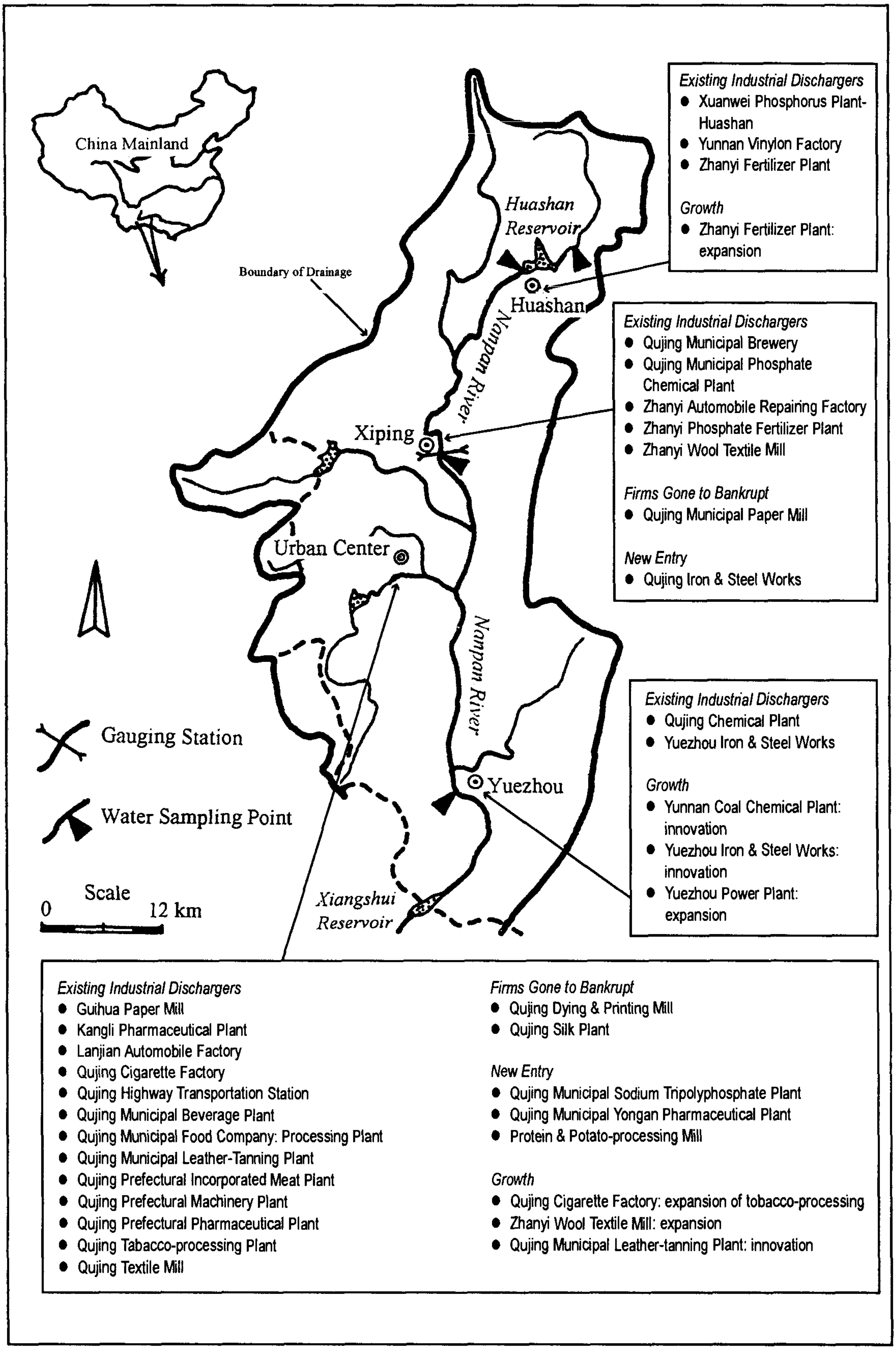

Figure1. Sketch of the Upper Nanpan River Catchment

Industrial development and urbanization played an important role in poverty alleviation. On the other hand, increasing industrial effluents and municipal sewage contributed to the deterioration of river water quality. As one of the major development zones in Yunnan province, Qujing city will be the site of remarkable change in terms of gross industrial output value and urban population (YIES, 1995). The pollutant loads will be much larger than the TMLAs. Water pollution prevention and control will be a significant challenge to the catchment. Nonpoint sources contribute somewhat toward instream water pollution, though contribution of point sources (industrial and municipal) is, and will be more, significant. In other words, controlling of point sources would make a significant difference in the river water quality.

2.2 Critical Actions for Water Pollution Control

With increasing amounts of pollutant loads produced due to accelerated economic development, water quality objectives became impossible to attain by enforcing the concentration limits of the existing national discharge standard (OLGTPS 1993). Therefore, a non-tradable permits system for water pollution of the upper Nanpan river in Qujing city was developed. It was designed to control effluent discharges of point sources in terms of the total daily loads of NH_3-N, COD, fluoride, cyanide, phenol, and lead. The permits system has been tested since 1992 and wasteload allocations for industrial point sources were granted to the 30 major industrial dischargers.

Wasteload allocation considered the municipal sources, but no compliance requirements were designated. To pass the World Bank loan appraisal for the Qujing Municipal Wastewater Treatment Plant (QMWTP), the feasibility study and design work have been completed. Construction is anticipated to commence this year. The QMWTP is designed to collect and treat the municipal wastewater from the Qujing urban center, with a design capacity of 70,000 ton/day before 2000. The ultimate capacity will be up to 150,000 ton/day.

The Yunnan provincial government has resolved to carry out comprehensive water pollution control. Thus the Water Pollution Prevention and Control Planning of the Upper Nanpan River Basin (YIES 1995) was completed in 1994. The planning involved extensive preliminary examination of pollution control options of almost all 30 major industrial dischargers. It examined in detail pollution control of five crucial industrial dischargers and domestic sewage systems. As mentioned earlier, its recommendation for the construction of a municipal wastewater treatment plant in the urban center has been implemented. It also suggested the trading system (i.e., the trading program would be an integral part of the whole comprehensive water pollution control plan).

The planning report laid a foundation for data/information collection and analysis of this project, including ambient water quality monitoring results, full profile of existing dischargers, prediction of future discharges, TMLAs for each instream subzones; and preliminary examination against pollution control options of major industrial dischargers and municipal sources.

2.3 Options Available to Address Water Quality Problems

2.3.1 Environmental management systems in place

The current non-tradable permits system is a component of a larger comprehensive environmental management strategy for pollution control of the upper Nanpan river. It covers the following:

- Environmental impact assessment of construction projects;
- "2-in-1 at three phases" for construction projects (i.e., the pollution control facilities must be designed, installed and operated parallel to the main engineering);
- Over-standard effluent charges;
- Responsibility system for attaining environmental targets;
- Quantitative examination of comprehensive treatment of urban environments;
- Deadline control of major industrial pollution sources;
- Permits system; and
- Centralized pollution control.

A preliminary examination (Tao 1995; YIES 1995) determined that even if a combination of the existing water pollution control instruments could achieve the TRTs, the approach would not be cost-effective with respect to the difference in unit reduction costs across dischargers. Thus, a TDP system was proposed.

2.3.2 Effluent charge

China's experience with effluent charge has not been studied systematically, but anecdotal critiques have created the impression that the system is arbitrarily administered and ineffective as a pollution control instrument (Wang and Wheeler 1996). Yun (1997) found that 76 percent of enterprises believed that it served more to enhance the environmental conscience than as an incentive to pollution control.

- The levy system only charges against the discharge in excess of the effluent standard. It is commonly believed that the levy in China provides little incentive to control pollution because official rates are below marginal abatement costs (Wang and Wheeler 1996).
- Most dischargers consider the levy system as a financing mechanism so that the fee cannot be levied in full at the low rate, not to mention raising the rate to the marginal reduction cost. Strictness of enforcement is thought to vary widely, so factories in different regions face very different penalties for polluting (Wang and Wheeler 1996).
- The charge level could be changed upward over time. In fact, such small increases have always been affected by inflation. As a result, such efforts contribute little to improvement.

Nevertheless, Wang and Wheeler (1996) concluded that the water pollution levy in China had been more effective than previously assumed, although there was undoubtedly much room for improvement. According to the relevant regulations, the effluent fee in China will be charged against the total pollutant load rather than only the over-standard load.

In general, shift of current non-tradable permits system to the TDP does not contradict with improvements of the levy system. It is possible to design economic instruments that contain elements of price and/or quantity controls, such as tradable permits combined with effluent fees (NSW EPA, March 1994). A survey on Chinese enterprises' behavior (Yun 1997) also found that 43% - 55% of the interviewed enterprises preferred 'controlling pollution while paying the charges'.

2.3.3 Stricter enforcement of existing command-and-control management systems

In theory, a similar outcome of market-based instruments could be achieved by a central authority applying traditional command-and-control techniques. However, interviews in the United States indicated that regulators were generally reluctant to allocate load reduction requirements on the basis of marginal costs, because this approach was viewed as less equitable than options based solely on pollutant loading (US EPA, May 1992). Traditional approaches may have higher administrative costs than trading, because they would require central collection and analysis of cost data. In addition, dischargers are likely to protest schemes that allocate a larger share of the control costs to them if there is no mechanism to provide monetary compensation (US EPA May 1992).

As a matter of fact, even full enforcement of existing concentration-based discharge standards - Integrated Wastewater Discharge Standard of the People's Republic of China (IWDS) - could not keep the total discharge loads under the TMLAs (OLGTPS 1993; YIES 1995). Nevertheless, some form of direct regulation will be necessary to support market mechanisms or to reach management objectives other than economic efficiency (NSW EPA, March 1994). For example, one of the necessary conditions for a successful TDP program is that the IWDS must be met.

2.4 Institutional Structure of Environmental Management

The administrative agencies in charge of environmental protection in China consist of those at the state, province, prefecture/city, and county levels. They administer and supervise environmental protection affairs within their areas of jurisdiction.

The Qujing Prefectural Environmental Protection Bureau (QPEPB) and QMEPB are executors of national and/or local laws, regulations and policies on environmental protection. The Qujing Municipal Leaders Group for Testing the Permits System for Water Pollution (LGTPS) was established temporarily to take charge of coordinating pertinent sectors and approving wasteload allocations under the permits system. LGTPS comprised leaders of QPEPB, QMEPB, and other associated government agencies. Since January 1993, LGTPS has delegated the management and supervision of permits of the city-owned industrial dischargers and province/prefecture-owned dischargers to QMEPB and QPEPB, respectively. Such decisions as adopting the TDP will be made by the EPBs.

2.5 Principles of Point/Point Source Trading

Under the traditional 'command-and-control' approach to water quality protection, dischargers are required to comply with effluent limitations, but no direct incentive exists if they take additional steps to further reduce their discharges (US EPA, April 1992). Trading programs seek to achieve pollution reduction targets in the most cost-effective manner by providing flexibility to the dischargers. By establishing a market for buying and selling such allowances among themselves, the economic incentives provided by the market forces presumably allocate the control requirements to the dischargers with the lowest control costs. To date, three distinct trading scenarios (US EPA, April 1992) have emerged:

- those that permit trades only among point sources (PS/PS trading);
- those that permit trades between point sources and nonpoint sources; and
- those that permit trades between nonpoint sources.

The theory underlying effluent trading is based on marginal cost analysis (US EPA, April 1992). The marginal costs of technological control measures differ among point sources. Under PS/PS trading, a regulated point source is allowed to avoid upgrading its pollution control technology to meet permit limits if it pays for equivalent (or greater) reductions in one or more other point sources within the allowed trading area. Presumably, the plants might pay for reductions at the plant that could achieve the lowest pound-for-pound reduction costs until the reduction targets are met or until the marginal cost of treatment is equalized among the point sources (US EPA, May 1992).

The dollar values of costs and benefits of trading programs will vary according to water body size, number and type of affected dischargers, and program design (US EPA, May 1992). Theoretically, benefits that might result from trading relative to non-trading policy include the following:

- producing direct cost savings from trading;
- providing the dischargers with flexibility to control pollution;
- providing incentives to develop more cost-effective pollution control systems; and,
- minimizing delays in complying with effluent reductions.

The actual results of PS/PS trading should be relatively certain because it is easier to monitor point sources than nonpoint sources (US EPA, May 1992). However, this scenario does not present a truly comprehensive solution to water quality problems where non-point sources are significant.

2.6 Necessary Conditions of Point/Point Source Trading

A PS/PS trading program is considered efficient and effective if it achieves pollution reduction targets at the lowest aggregate cost, including point source controls and administrative costs. However, many economic, technical, and institutional factors must be considered when developing a trading program for a specific catchment. The case studies of specific water bodies, national screening analysis, and the Fox River experience in the USA, have identified several conditions that appear necessary for an efficient and effective trading program (US EPA, April 1992; US EPA, May 1992). This report extracts the necessary conditions for an efficient and effective PS/PS trading program. Key elements include the following:

Identifiable catchment

The trading must be confined to an identifiable watershed or segment. This will facilitate the management of the trading program by establishing the boundaries in which trading is allowed and delineating the area that will be monitored for water quality improvement as a result of trading.

Significant and sufficient point sources

The point sources must contribute a significant portion of the total pollutant load, and the water quality problem must result from multiple point source dischargers in order for trades to be possible. The more diverse the dischargers, the more likely that trades beneficial to both the traders and the environment will take place.

Established total maximum discharge loads allowable

There must be a positive difference between the existing or projected discharge loading and the TMLA that provides a practical base to force action. The TMLA and the resulting loading allowances then serve as part of the basis for dischargers to evaluate the cost-effectiveness of further controls to meet these limits. It also serves as the base against which reductions are measured and effectiveness of the trading approach can be determined. The TMLA is designed to achieve a specified ambient water quality objective. It may reflect a reduction over current point source loading, and may decrease over time to force improvement of water quality.

Accurate and sufficient data

Reliable and sufficient data and information about water quality, pollutant loads and water quality effects are necessary to determine TMLAs and TRTs, and measure reductions. Stream characteristics and the distance between dischargers are such that the further load reductions contributed by each discharger can be shifted while still meeting overall water quality objectives. It is also necessary to have detailed information about point source facilities in order to determine the marginal costs of point source controls.

Required discharge limitations

Point sources must meet and continue to meet, at a minimum, the national/local discharge standards. Trading may not result in increased loading for any individual point source above that allowed by technology-based or concentration-based discharge requirements. Some point source facilities are required to upgrade treatments, otherwise there will be no reason to trade. Furthermore, trading must result in significant reductions for a trading program to have significant impact on water quality, and thus reduce the likelihood that point sources will be required to meet more stringent discharge limits.

Large difference of treatment costs across dischargers

The relative cost-effectiveness of treatment across the affected dischargers influences the benefits from trading because it determines the savings that can accrue as trading shifts treatment requirements from high-cost dischargers to those with lower costs. Current (or anticipated future) treatment costs must differ across dischargers by a large enough amount to provide incentives for trading; there must be significant load reductions remaining accompanied by a large difference in marginal costs across individual dischargers. Otherwise, there is no incentive for trade to achieve reduction targets.

Acceptance of community and regulatory agency

Factors influencing participation must be addressed in the program planning stage. These include the regulatory agency's perceptions of the effects of trading on environmental quality, the willingness and potential capacity to carry additional workloads, and the competitive pressures that can inhibit trading by industrial dischargers.

Dischargers may have chosen not to participate in trades for reasons (e.g., desire to increase market share) beyond the scope of the program. Then, the local community must support a trading program as one way to achieve pollution reduction targets.

Adequate institutional structure

While trading programs are based on market incentives, they cannot rely entirely on market forces to result in attainment of water quality objectives. There must be an institutional structure to facilitate trading, design the program so that it encourages dischargers to engage in trades, and monitor program results. Because trades affect the permit requirements of dischargers, feedback is needed by the agency responsible for permit issuance, review, and enforcement. In addition, if water quality objectives are not being met under a trading program, then the implementing agency needs to be able to revise permit levels, trading rules, and possibly program design. Basically, the TDP management institution must have adequate legal authority.

Adequate compliance incentives and enforcement mechanisms

A program that departs from traditional point source permit requirements raises compliance concerns. Implementation mechanisms are important in creating compliance incentives where economic incentives are absent or have failed. A sufficient and effective implementation mechanism must be a component of the trading system. Inadequate enforcement could mean loss of any environmental gains made from controlling discharges, whether through a trading scheme or direct regulation.

3.0 POTENTIAL APPLICATION OF PS/PS TRADING TO THE UPPER NANPAN RIVER

3.1 Current Non-Tradable Discharge Permits System of the Upper Nanpan

Thirty major industrial enterprises along the upper Nanpan river in Qujing city were determined to be the participants of the non-tradable permit system (see Appendix 1). Statistic analysis found (YIES, 1995; OLGTPS, 1993) that COD, BOD_5 and NH_3-N were the crucial pollutants. The discharges of COD and BOD_5 of the 30 participants amounted to about 80% of the total industrial loads; and NH_3-N discharge of the 30 participants amounted up to nearly 100% of the total industrial loads (YIES, 1995; OLGTPS, 1993)., The percentage must be higher for small enterprises with indigenous production processes since September 1996, at least over 90 % for COD and BOD discharge if giving an empirical estimation.

The current non-tradable permits system was designed to control effluent discharges of point sources in terms of daily TMLA of NH_3-N, COD, fluoride, cyanide, phenol and lead. The permits system now covers the upper Nanpan river segment downstream of the Huashan reservoir, including instream subzone 2-5.

The TMLAs aimed at by the permits system (either trading or non-trading) were derived with consideration of the water quality background - baseline at the Huashan reservoir. Research (YIES 1995; OLGTPS 1993) found that the TMLAs for crucial pollutants of the upper Nanpan river were much less during the low-flow seasons than during high-flow conditions. Thus, the nontrading permits system uses the TMLAs derived from the low-flow instream conditions. The 1-in-10-year monthly low flow is usually employed for water quality control in China.

Initial waste allocation of the TMLAs adopted 'grandfathering' - an allocation of permits to existing sources commonly based on historical discharge levels. The municipal allocations were first calculated and the residue was then given to the industrial sources. The same formula of wasteload allocations for the regulated pollutants was adopted (OLGTPS 1993) as follows:

- Municipal allocation = TMLA * (Current municipal load/(Current municipal load + Current industrial load))
- Industrial allocation = TMLA - Municipal allocation
- Allowances of major industrial discharger i = Industrial allocation * (Standard discharge of discharger i) / Σ (Standard discharge of discharger i)
- Standard discharge of discharger i = Volume * Discharge standard in concentration
- Allocations for minor industrial dischargers and growth/entry = Industrial allocation - Σ (Allowances of major industrial discharger i)

Industrial wasteload allocation was given to the 30 major existing industrial dischargers (Appendix 1) and the deadlines for meeting the effluent limits were delineated specific to each permit holder. The farthest compliance deadline is December 1999. In fact, some dischargers had not made their effluent meet the permit limits by the deadline owing to weak enforcement to a great extent.

Those enterprises that contribute little to the river water pollution are not covered by the permits system and are required only to comply with the national IWDS in terms of pollutant concentration. Discharges of the other pollutants are also controlled by the IWDS.

In principle, the current permit system apportioned the TMLAs among the major existing industrial dischargers, major new industrial sources, and the municipal sources (i.e., the current permit system did consider the future industrial growth/entry). However, no meaningful amount of wasteload allocations was reserved for new point sources when wasteload was allocated initially.

3.2 Public Participation

For the upper Nanpan river catchment, perhaps the most significant obstacle to the TDP system as a management alternative is the lack of acquaintance with the trading concept and a shortfall of funds to develop practical technical guidelines and an administrative framework. This project provided the local environment managers and the dischargers with an opportunity to participate. It also disseminated TDP concepts, and subsequently helped in acceptance of the trading program, through two seminars and other contacts:

- Local seminar 1, May 19-20, 1997 at Qujing—mainly on disseminating the permits trading concept to environmental managers. The participants came from environmental protection bureaus, environmental monitoring centers and other relevant organizations in the Nanpan river basin.
- Local seminar 2, August 14-15, 1997 at Qujing—mainly on disseminating the preliminary findings of this study to environmental managers and potential trading participants. The participants came from environmental protection bureaus, environmental monitoring centers, and potential trading participants in the upper Nanpan river catchment.
- Contacts with the industries during additional collection of data and information for this study.
- A meeting with the leaders of QPEPB and QMEPB during the project adviser's visit in February to the upper Nanpan river.

Since these local seminars and other contacts were solely non-governmental, the seminar participants and interviewees from the industries would not write their opinions of the proposed trading system. However, their casual remarks indicate the following:

- They had always overlooked the need for careful TDP program design; thus, the program must be designed as simply as possible, at least for the pilot period.

- The managers were worried about the permit reallocation method and permit lifespan because of the more acute problems of equity and financial benefits under the trading program. One thing the industries commonly worried about was whether they would get their excessive allowances while permits were reallocated.
- Both managers and industries surmised relatively low transaction costs.
- At the planning stage of the trading system, it was difficult to get seminar participants to express what would make them participate in the trading. Most of their comments were as general as "The program is promising theoretically" and "We'd like to seek trades as an alternative to attain our pollution permit limits if the government puts the trading system into effect."

3.3 Status of Upper Nanpan River Regarding Necessary Conditions for PS/PS Trading

The trading will not be uniformly applicable to all watersheds or segments. The absence of one or more necessary condition will result in the delay of trading or will eliminate the need to shift to trading. This part examines the upper Nanpan river catchment for presence of the necessary conditions for an efficient and effective point/ point source trading program, and evaluates the degree to which the catchment meets these conditions.

In general, future prospects appear good for a PS/PS trading program for the upper Nanpan river catchment. The catchment meets eight of the nine conditions. Meanwhile, recommendations for dealing with the inadequacy or constraints are proposed.

Is the Waterbody Identifiable as a Watershed or Segment? **Yes**

The upper Nanpan river is an identifiable water segment within the larger Nanpan river basin. This segment is entirely in the jurisdiction of Qujing city, and is divided into five subzones (see Section 1). The reach covering instream subzones 2-5 has been identified as a discrete segment for the current permits system. The effluent trading zone may be confined either to the same area as that of the current system or to certain subzones.

Are Point Sources Dominant and are there Sufficient Point Sources? **Yes**

Nonpoint sources contribute somewhat toward instream water pollution, though point sources (industrial and municipal) contribute significantly to the total loads of the crucial pollutants and will be dominant (Table 3). In addition, a certain part of the nonpoint source load is natural or uncontrollable. Comparison of the current and projected discharges with the TMLAs, manifests that the enforcement of point source pollution controls alone would make the TMLAs attainable (with exception of the TMLA of NH_3-N by 2010).

Nearly 30 existing industrial dischargers participating in the current permits system, future industrial growth/entry, and the municipal sources could form a wider trading market. The existing and future industrial dischargers encompass diverse sectors such as chemical industries, textile, papermaking, food processing, brewery, and machinery.

With respect to the pilot program in a smaller trading zone proposed hereinafter, there are 18 industrial and two municipal participants. Twelve potential industrial and two municipal traders were identified, which could form a relatively thick trading market in comparison to the number of potential traders in the American case studies.

Have the Total Maximum Loads Allowable Been Established? **In general, yes**

A non-tradable permits system for water pollutant discharge is in place in the upper Nanpan river catchment. A detailed TDP program could be developed on the basis of the current permits system, or TMLAs and TRTs for the regulated pollutants could be handed down. The existing wasteload allocations may also be adapted as an options for initial allocation for trading.

The technical report of the current non-tradable permits system (OLGTPS 1993) used a very simple model for calculating the TMLAs of its regulated pollutants, considering the whole upper Nanpan mainstream as a fully-mixing flow with uniform degradation coefficients. The substantial defect of the water quality model is that it could not adequately examine the water quality effects. At the same time, it sets forth the need for developing more accurate water quality models to improve the accuracy and reliability of the modeling. YIES (1995) developed one-dimensional instream water quality models for NH_3-N, CODcr, and BOD_5. These new models can be used to develop more reliable TMLAs of each instream subzone and to modify allocations while designing the trading program.

Are there Accurate and Sufficient Data? **In general, yes**

All the participants are required to report their discharges — monthly for dischargers with monitoring capacity, quarterly for major dischargers, and annually for small dischargers. Occasional monitoring at the outlets is undertaken for compliance inspection. The discharges are always monitored when environmental impact assessment is conducted for expansion or renovation purposes.

The YIES (1995) has assessed the wastewater characteristics of the major dischargers and investigated water pollution control strategies and associated costs of individual dischargers. In the preparation phase of the QMWTP, the costs of urban wastewater treatment have been studied extensively with different design capacity and effluent limitations. In order to comply with the permit limits and meet deadline control requirements, many industrial dischargers themselves have investigated their water pollution control options and associated costs.

One important fact is that these data and information are kept by different managers of the EPBs, research institutions and other persons/organizations. Thus, data/ information differences among sources are common. Most of the data used by this project are from YIES (1995) which presented coherent sets of data about the discharge characteristics and the instream water quality as of 1993. To make full use of these continuously developed data/information, a computer information system should be set up. The system would save on resources of both regulatory agencies and players of effluent trading.

Must the Concentration- or Technology-based Discharge Requirements Be Met At a Minimum? **Yes**

In general, TMLA is developed and enforced for catchments where concentration- or technology-based discharge requirements could not maintain or attain the designated water quality objectives. In such cases, TMLA is assumed to be a more stringent discharge limit. Except for the municipal sources, all industrial point sources in the catchment must, at a minimum, meet the concentration-based discharge requirements of the IWDS.

The IWDS imposes different requirements upon existing and future sources. A new industrial source must be designed to meet the IWDS if there is no wasteload allocation, and has to meet both the IWDS and the mass load requirements if wasteload allocation has been done. All the existing industrial dischargers must meet the discharge requirements of IWDS by year 2000.

With respect to the industrial dischargers registering for the current permits system, about half of the participants are facing requirements to increase reductions both to meet their effluent limitations and to achieve permit limits.

Is there a Large Difference in Treatment Costs Across Dischargers? **Yes**

At the time the initial allocations for COD discharge were approved by the LGTPS, 13 of the 26 industrial participants faced significant reductions and 13 held allowances for COD discharge equal to or a little higher than their actual discharges (Appendix 1). To date, few industrial participants had achieved their permit limits by upgrading treatment capabilities. One facing significant reduction was almost bankrupt. The municipal sources received wasteload allocations, but no permit limits were put on municipal wastewater discharge. Therefore, the remaining reductions were large enough for potential trading.

As a result of the wasteload allocation and dischargers' efforts to achieve their permit limits, some of the existing dischargers possessed allocations, a few faced advanced treatment requirements, and others only needed primary treatment. Analysis on pollution control options and associated costs is conducted (Appendix 3) and shows that the remaining large reductions are accompanied by difference in annual unit costs of pollution control across dischargers (from CNY88.6/kgCOD/day to CNY7393.3/kgCOD/day). The combination of required reductions and unit costs makes a large enough difference in treatment costs across dischargers, consequently providing incentives for trading (Tables 6 and 7).

Do the Regulatory Agency and Dischargers Accept the TDP Program? **Yes**

Although a national or local regulatory/administrative framework of TDP system for water pollution does not exist, China has generally approved the rights to trade permits. The amended (1996) Water Pollution Prevention and Control Act of People's Republic of China delegates to local government the decision to adopt trading to meet TMLAs. Even if the TDP is applicable economically and technically to the upper Nanpan river, whether or not the program is adopted will depend to a certain extent upon the managers' opinions. QMEPB staff were supportive of and committed to trading.

The industrial dischargers were not familiar with the trading concept prior to this study. To what extent they would seek to trade permits was difficult to determine, though no one expressed opposition to the trading program during the local seminars and occasional contact with industries.

QMWTP will be constructed with a World Bank loan and domestic investment. The World Bank required that the Plant be managed by a private entity. According to relevant state regulations, fees could be charged against its users to repay the investment. Moreover, the Plant will be the largest participant of the trading program in terms of wasteloads. That would ensure it a positive position in the trading market.

Wasteloads of municipal sources are less subject to market changes over time compared to industrial sources. Since their loads are relatively predictable, municipal sources may buy short-term discharge allowances while waiting for a specific level of load increment to upgrade their treatment facilities. They could also sell their excessive allowances for given periods to avoid wasting their newly-extended wastewater treatment capacity. Considering all these, it is felt that the municipal sources will participate in permits trading actively and seek to make money in the trading market.

Is there an Appropriate Institutional Structure? **In general, yes**

The region has a sufficient capacity for environmental monitoring in support of trades. The Qujing Municipal Monitoring Station and the Qujing Prefectural Monitoring Station carry out instream water monitoring and effluent monitoring on a regular basis under the National/Provincial Environmental Monitoring Networks. Occasionally, they assist in environmental impact assessments and other activities.

Although a specific institutional structure to facilitate trading and design the program needs to be determined formally, QMEPB and QPEPB appear to be good candidates for assuming all of this authority/responsibility. They have shown their capability for permits system management, though both are in need of further capacity building.

Are Sufficient and Effective Compliance Incentives and Enforcement Mechanisms in Place? **In general, no**

Under the current permits system, whether a polluter complies with its permit limits is commonly assessed through self-reporting of discharges and occasional monitoring of results. On one hand, the EPBs do not have enough personnel and resources to conduct unannounced checks. On the other hand, bargaining is the predominant phenomenon in economic activities owing to the special relationship between the government and the enterprises (Yun 1997). With respect to discharge permits, they may bargain either to extend the deadline to comply with their permit limits, or to get rid themselves of/reduce the penalty for non-compliance. Enterprise behavior is determined not only by internal motivation, but by the external environment which includes the changing economic system and enforcement by authorities, among others (Yun 1997). It is felt that implementation mechanisms are not yet in place. If these constraints are resolved, the upper Nanpan river stands an excellent chance of developing a successful PS/PS trading program.

The National Environmental Protection Agency of China has realized there are enforcement problems and is seeking technical assistance to formulate an enforcement policy of environmental legislation. Moreover, environmental performance motivates enterprises to invest in pollution control as China's market system expands.

The compliance incentive is highly affiliated with design. Therefore, this study sets forth other concerns important to implementation (e.g., permit reallocation method, compliance monitoring, design guidelines). One important thing that is beyond the trading program design but that should be given attention is that public exposure through mass media always has remarkable influence on the polluter's behavior in China.

3.4 Specification of the TDP for Water Pollution of the Upper Nanpan River

Careful program design is needed to ensure that the predicted benefits of trading accrue in practice. Here it is not intended that the design issues be addressed. However, to illustrate the cost savings of the trading program, the scope and objective-pollutants to be covered, geographical area, participants and total maximum loads allowable-are specified first.

Thus, point/point source trading system for COD and BOD_5 discharge is proposed for the upper Nanpan river, covering both existing and new point pollution sources in the vicinity of Xiping town and the Qujing urban center. The trading system will be based on the current non-tradable permits system. It will impose market forces upon the permits system to provide the dischargers with flexibility in pollution control.

3.4.1 Objectives

The point/point source trading system for the Nanpan river segment is proposed for the following reasons:

- to achieve the TRTs at lower total cost than the nontrading permits system;
- to provide opportunities for point sources that would otherwise have to install high-cost technologies to pay for generally less expensive point source controls (i.e., in a flexible manner); and
- to provide a way to ensure ongoing financial incentives to further reduce pollution.

Further, trades can be used for relatively short-term periods to cover emergencies, and to allow short-term shutdowns in the wastewater treatment facilities. They can be sold when planned production shutdowns occur.

3.4.2 Controlled Pollutants

Effluent trading, more than regulations, could be a more efficient means of controlling discharges of non-persistent pollutants into water (Government of Canada 1992). Assessment found that at least before the year 2010, only the crucial pollutants of NH_3-N, COD and BOD_5 will be suitable for total mass loading control. It would be simpler to manage and more effective to control other pollutants by the concentration approach (Tao 1995; YIES 1995). Nevertheless, NH_3-N is, and will be, from only a few dischargers. Both the non-tradable and tradable permits system use the approach of total mass loading control. Therefore, COD and BOD_5 are proposed as the pollutants to be controlled by the trading system.

The controlled pollutants are those for which discharge allowances could be traded among participants in the trading system. Pollutants should be subject to separate trading programs because their environmental impacts are different (Government of Canada 1992). Principally, allowances for COD and BOD_5 should be traded separately in the Upper Nanpan river. Considering the common characteristic of oxygen consumption due to both COD and BOD_5, it seems proper to allow trades between COD and BOD_5 as long as an appropriate trading ratio is specified. But this design issue is beyond the reach of the project.

3.4.3 Trading Zone

The trading zone of permits system is the geographical area within which dischargers of a given pollutant would be allowed to buy and sell permit allowances. For a trading program to be successful, appropriate boundaries must be set for the trading zone. The coverage of these boundaries can affect the potential cost savings and improvements in water quality (NSW EPA, November 1994). Generally, the greater the number of sources targeted by a permit system, the greater the likelihood the permits will be actively traded among firms (Government of Canada 1992). If the trading area is very small and few dischargers are included, there may be limited opportunities for trading. However, in over-large trading areas, monitoring and enforcement may be difficult, and local 'hotspots', a problem.

Both calculation and allocation of TMLA in the Nanpan did not consider the difference of water quality effects of dischargers at different locations due to lack of instream purification data and instream flow analysis. YIES (1995) gave TMLAs for each subzone separately. It would be preferable to circumscribe the trading zone not only to avoid remarkable environmental 'hotspots' - localized areas in which instream water quality standards are exceeded, but also to make the trading market thick enough.

With regard to the distribution of existing and future dischargers, it would be pragmatic to establish a demonstration trading program within the instream Subzones 3 and 4—a total channel length of 38 km. Pollutant discharges are prohibited within the first subzone in order to maintain the water quality of Huashan reservoir. Most of the dischargers along the upper Nanpan river are within subzone 3 and 4, and the channel distance between their discharge cores (Xiping town and the urban center) are relatively short. There are few dischargers in Subzones 2 and 5.

3.4.4 Participants

Ideally, from an environmental and economic standpoint, all sources of pollution within the trading zone would be included in a given trading program. Frequently, however, it would be administratively costly and impractical to include directly many small sources (Government of Canada 1992). It would be more cost-effective to include the larger sources in the permit program on a mass load control basis, while applying concentration control to the smaller sources (Tao 1995).

Point sources in the trading system turn up in two classes, industrial dischargers and municipal sources. The trading system could contain all the 18 existing industrial participants of the non-tradable permits system in the trading zone and the two major municipal sources (Table 4). Also, future industrial dischargers could be brought into the trading program. If all the pollution credits were issued in the initial allocation, then anybody who made an application to develop a new pollutant source, or to increase discharges from an existing source, would first need to purchase sufficient credits from existing market players (NSW EPA, March 1994).

3.4.5 Total Maximum Daily Loads and Initial Allocation of Permits

YIES (1995) gave each subzone a TMLA during low-flow conditions that could be considered in implementation of the trading program. The TMLAs in low-flow conditions do not take into account the contribution of nonpoint sources and could then be apportioned to the point sources within the trading zone.

The initial allocation will affect the bargaining power of participants in a trading program (e.g., by determining which participants start out with the largest allowances), and therefore needs to be designed carefully to support the program's goals (US EPA, May 1992). Several methods for allocation of permits under non-tradable systems are described in relevant official guidelines in China. 'Grandfathering' is commonly used for initial allocation of permits, as in the case in the upper Nanpan river.

As a matter of fact, there are a few methods for permits allocation that appear appropriate for the tradable permits system—modifying the current allocations, rewarding existing dischargers that have already finished their deadline control requirements, growth/entry that adopt cleaner production and/or China's best practical environmental technology, and auction, among others. It is no simple matter to select the most relevant for particular cases. Hence, alternatives for initial allocation of permits is hereafter identified as an important concern to be addressed in later stages. To simplify the benefit analysis, existing allocations are used to estimate the cost savings of trades at the present stage.

4.0 BENEFITS OF TRADING PROGRAM FOR THE UPPER NANPAN

The cost-effectiveness of a TDP system must be analyzed, and compared to those of the non-tradable system to examine the social benefits of the trading system. Estimation of any TDP system's benefits is difficult before the system is actually in place, for the actual level of benefits depends largely on the extent of trading (US EPA, May 1992). In addition, even if the program had been designed to encourage stronger trade, dischargers may have chosen not to participate in trades for reasons beyond the program's scope (US EPA, May 1992). The research intends to help the governments and industries accept the TDP system by illustrating the benefits from trading rather than giving an exact estimation of benefits.

4.1 Target Load Reduction Requirements

Since BOD_5 is not regulated by the current permits system (i.e., no wasteload allocation was undertaken), benefits analysis puts emphasis on COD discharges of the participants within the trading zone.

Table 4. Target Reduction of the Existing Participants for COD Discharge

Dischargers	Actual discharge kg/day	Permit limit kg/day	Required reduction kg/day
Municipal Sources			
QUC	9966.60	1158.90	1542.21
XT	385.55	8424.39	773.35
Industrial Dischargers			
1. QMB	77.00	29.41	47.59
2. QMPCP	0.06	0.00	0.06
3. ZARF	5.35	5.35	0.00
4. ZPFP	23.05	0.00	23.05
5. ZWTM	64.00	80.88	-16.88
6. GPM	296.38	39.32	257.06
7. KPP	0.35	0.01	0.34
8. LAF	94.20	94.20	0.00
9. QCF	857.00	88.85	768.15
10. QHTS	41.00	14.15	26.85
11. QMBP	54.00	7.55	46.45
12. QMFC	113.12	3.65	109.47
13. QMLTP	99.54	29.57	69.97
14. QPIMP	46.76	2.98	43.78
15. QPMP	0.07	0.07	0.00
16. QPPP	270.59	28.96	241.63
17. QTPP	1.67	1.67	0.00
18. QTM	1.07	1.07	0.00
Sum	3170.71	2355.45	10815.26

Actual discharges are as of 1993; permit limits allocated with the TMLAs by year 2000 are quoted from OLGTPS (1993).

Code of Dischargers:
QUC -Qujing Urban Center, XT-Xiping Town, QMB -Qujing Municipal Brewery, QMPCP -Qujing Municipal Phosphate Chemical Plant, ZARF -Zhanyi Automobile Repairing Factory, ZPFP -Zhanyi Phosphate Fertilizer Plant, ZWTM -Zhanyi Wool Textile Mill, GPM -Guihua Paper Mill, KPP -Kangli Pharmaceutical Plant, LAF -Lanjian Automobile Factory, QCF -Qujing Cigarette Factory, QHTS -Qujing Highway Transportation Station, QMBP -Qujing Municipal Beverage Plant, QMFC -Qujing Municipal Food Company: Processing Plant, QMLTP -Qujing Municipal Leather -Tanning Plant, QPIMP -Qujing Prefectural Incorporated Meat Plant, QPMP -Qujing Prefectural Machinery Plant, QPPP -Qujing Prefectural Pharmaceutical Plant, QTPP -Qujing Tobacco-Processing Plant, QTM -Qujing Textile Mill.

Among the permits system, 18 industrial participants in the trading zone, ten dischargers face significant COD load reductions, one holds excessive allowances, and one has no reduction requirement. All of the 12 industrial dischargers plus the two main municipal sources are potential participants of the trading program. Six dischargers have achieved negligible discharge level and would participate in the trading program unless allowances are rewarded during the reallocation process. Therefore, only the potential participants of the trading program are involved hereinafter.

4.2 Pollution Reduction Options and Costs

Although no reduction cost vs. pollutant discharge curves exist for catchment dischargers, various pollution reduction options and the costs associated with different reduction levels could be identified from many data sources. Selection of reduction options and cost-effectiveness analysis were conducted in detail (Appendix 2).

The annual reduction cost, the sum of annualized capital cost and annual operation and maintenance (O&M) cost, is employed to compare the total cost of pollution reduction options. Conversion of one-time capital costs to annual equivalent capital costs allows consistent comparison of the total costs of reduction options. Annual capital cost is derived from the following formula:

$$\text{Initial Investment} = \sum_{t=1}^{k} \left(\text{Annual Capital Cost}/(1+r)^t\right)$$

where r is the discount rate and k capital recovery period. The wastewater treatment plants (WTPs) or facilities (WTFs) are assumed to depreciate over a 20-year period and the discount rate is then 5%. Capital cost of industrial dischargers embraces costs of wastewater collection system, civil construction, equipment and installation of WTP/WTFs, and waste-reclamation. Capital cost for municipal sources mainly includes land cost, civil construction cost, and equipment and installation cost. The principal elements of O&M are labor, energy, chemicals, materials and supplies.

To seek options that appear feasible in actual circumstances, the pollution reduction options and associated annual costs are obtained in the following process:

- Characterize participants' wastewater with existing available information/data.
- Evaluate the existing wastewater collection system, wastewater treatment facilities and internal water-reuse system with respect to capacity, processes, design snags and operational problems, and identify the remaining problems.
- Select water pollution reduction options. Most of the options are derived from the reference data/information sources. The most common sources include existing research reports, environmental impact statements, feasibility study reports, design specification, permits application documents, and government guidelines for best practical environmental protection technologies and cleaner production processes.

- Develop the annual reduction costs of each option using cost transfer method. This transfers unit cost adjusted to better reflect the conditions of the target reduction by a coefficient. All costs are converted to 1990 CNY, using the official composite price index. The sources used are relatively detailed and developed for local conditions. Hence, it is felt that they provide a reasonable approximation of actual reduction costs for the individual polluters considered in the study.

All reduction levels in Appendix 2 connote reduction from the current mass loading to the level corresponding to a specific engineering option. The options in Appendix 2 are those optimum feasible options relative to certain reductions, and the reductions to nearly 'nil discharge' or permit limit are sought. For this reason, it may be possible to find a few options for most of the participants so that a smooth incremental cost curve would not develop. Therefore, unit costs are used to identify trading opportunities.

4.3 Identification of Trading Opportunities

The trading opportunities are identified by comparing the unit costs as illustrated in Figure 2. In principle, effluent trading allocates pollutant load reductions across point sources using least cost as the criterion. So identification of trading opportunities starts at selling the excessive reduction due to the cheapest option. The most likely trade would occur when the participant with the highest unit cost to meet its permit limits offers the highest permit price for a unit excessive allowance on sale by the one with the lowest unit cost. There are exceptions to the rule, especially as the reduction limit is neared. Consequently, it is assumed that the participant with the most expensive option is the first to buy such a unit excessive allowance on sale.

Table 5. Scale of Pollution Control Cost Relative to Cost of Industrial Products

Code of Participant	Annual reduction cost to meet permits/ Industrial product value	Code of Participant	Annual reduction cost to meet permits/Industrial product value
QMB	0.64%	QHTS	0.10%
ZPFP	0.65%	QMBP	0.33%
ZWTM	0	QMFC	0.32%
GPM	7.33%	QMLTP	0.04%
LAF	0	QPIMP	0.22%
QCF	0.04%	QPPP	0.44%

Note: Annual reduction costs see Table 6. Industrial products are as of 1993

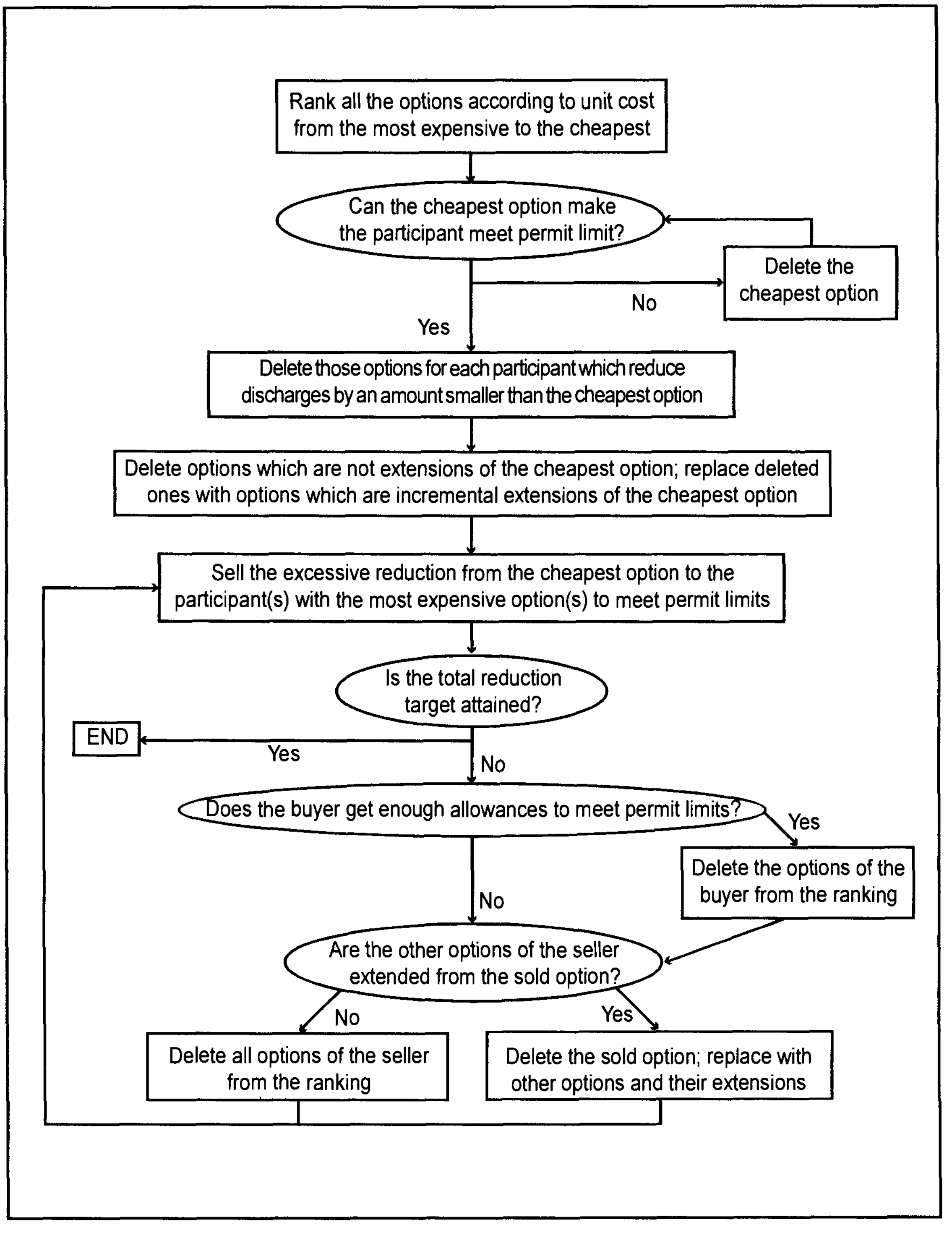

Figure 2. Illustration of the Process of Identifying Trading Opportunities

At the start of the current non-trading permits system, the actual load of a participant was either larger than or equal to the allowance. A specific control technology might result in a participant having excessive allowances. Nonetheless, few dischargers are assumed to solely seek financial gain by upgrading their treatment facilities and selling the excessive allowances, considering the low proportions of the cost needed to meet permit limits to the cost of industrial product (Table 5). This assumption is justified by the Fox River experience. The options of the buyer are then deleted from the ranking if the buyer gets enough discharge rights to meet its permit limits.

The amount of allowance that could be traded should, of course, be large enough to install a certain unit treatment process. Therefore, the other options which are not extended from the sold option in the engineering viewpoint are deleted from the ranking. The other options which are extended from the sold option are substituted by the increments of reduction and cost.

Although the research aims at examining the implications of trading in real settings, trading cases are hypothetical. The project is solely intended to illustrate the potential effect of such an alternative to the current permits system for water pollution control.

4.4 Estimation of Cost-savings

The potential annual benefit is equal to the direct cost savings obtained as the difference of the summation of annual costs of all participants to meet permit limits "without" trading and the summation of annual costs of all participants to meet permit limits "with" trading. The "without trading" approach requires each discharger to achieve its permit limits by upgrading WTFs; the "with trading" approach allows permit trading to be an alternative for the dischargers to achieve their permit limits.

Without trading, the calculation of the total cost is relatively simple. It is obtained by getting the sum of the reduction in costs of all participants' option that could achieve the permit limits. Under a trading program, there are two choices for the dischargers to meet their permit limits -- upgrading their own WTFs or buying allowances. Thus, the calculation of the total cost with trading is the sum of the reduction in costs of those participants that could meet their permit limits by upgrading their own WTFs and the reduction in costs through trades, until the total reduction target is met. From the social economic perspective, buying or selling allowance just results in transfer payments. The project estimated the cost-savings per year in 1990 CNY. It would be simple to compute the present values, but that was not needed for this project.

Exclusion of the municipal sources from the trading system may make the trading system forgoes trading benefits to some extent. On the contrary, however, inclusion of the municipal sources into the market might bring out monopolistic behavior. Therefore, both cases are considered while estimating the cost-savings from pollution reduction.

If the municipal sources do not participate in the trading system, only one case of trade is likely to occur: ZPFP buys allowance of 23.1 kg COD/day for CNY7,177/year from GPM and incurs annual cost-saving of CNY163,239, or 1.7% of the total annual cost without trading.

If the municipal sources participate in the trading system, there will still be only one case of trade between the industrial participants (GPM sells to ZPFP), but several trades between the Qujing municipal source and industrial participants (QUC buys from GPM, QHTS, QMLTP, QMB, QCF, QPPP and QMBP), and one case between the Qujing municipal and Xiping town sources (XT sells to QUC) are possible. Under such cases, trading save CNY2,412,299/year, or 18.4% of the total annual cost to attain the TRT without trading. Therefore, the trading program should be designed to include the municipal sources. But to prevent potential monopolistic behavior of the municipal sources, an industrial congregation could be instituted, or the government could set interventions to the permit price, which ranges between the unit costs of the seller and buyer. Permit price would generally depend upon negotiation between the seller and buyer.

Theoretically, trading makes the differential in unit costs approach zero across dischargers. The unit price of the last trade can approximately be considered the marginal pollution reduction cost of the upper Nanpan river catchment. If municipal sources participate in the trading program, that is CNY959/kg COD/day.

Table 6. Illustration of Cost-effectiveness With and Without Trading to Meet Permit Limits—excluding municipal sources

Code of Participant	Required Reduction kg/day	Selected Option (Without/ With trading)	Without Trading Reduction kg/day	Without Trading Annual Cost CNY	With Trading Reduction kg/day	With Trading Annual Cost CNY
QMB	47.59	1/1	50.0	27446	50.0	27446
ZPFP	23.05	2/GPM5	23.0	170416	23.1	7177
ZWTM	-16.88	/	0.0	0	0.0	0
GPM	257.06	5/5	296.8	92220	273.7	85038
LAF	0.00	/	0.0	0	0.0	0
QCF	768.15	6/6	857.0	537350	857.0	537350
QHTS	26.85	1/1	27.0	8375	27.0	8375
QMBP	46.45	2/	47.0	19166	47.0	19166
QMFC	109.47	3/3	109.5	13058	109.5	13058
QMLTP	69.97	2/2	85.0	40723	85.0	40723
QPIMP	43.78	3/3	44.0	8660	44.0	8660
QPPP	241.63	2/2	244.0	30721	244.0	30721
Total	1617.12		783.3	948135	1760.3	777714

Table 7. Illustration of Cost-effectiveness With and Without Trading to Meet Permit Limits —including municipal sources

Code of Participant	Required Reduction kg/day	Selected Option (Without/ With trading)	Without Trading		With Trading	
			Reduction kg/day	Annual Cost CNY	Reduction kg/day	Annual Cost CNY
QUC	8424.39	43+GPM5+QHTS2+QMLTP2+QMB2+QCF6+QPPP3+QMB3+QMBP3+XT2	9110.0	11344200	8424.4	9191898
XT	773.35	2/2	822.5	788800	804.5	771516
QMB	47.59	1/2	50.0	27446	47.6	23186
ZPFP	23.05	2/GPM5	23.0	170416	23.1	7177
ZWTM	-16.88	/	0.0	0	0.0	0
GPM	257.06	5/5	296.8	92220	257.1	79881
LAF	0.00	/	0	0	0.0	0
QCF	768.15	6/6	857.0	537350	768.2	481661
QHTS	26.85	1/1	27.0	8375	27.0	8375
QMBP	46.45	2/2	47.0	19166	47.0	19166
QMFC	109.47	3/3	109.5	13058	109.5	13058
QMLTP	69.97	2/2	85.0	40723	70.0	33537
QPIMP	43.78	3/3	44.0	8660	44.0	8660
QPPP	241.63	2/2	244.0	30721	244.0	30721
Total	10814.86		11715.8	13081135	10866.4	10668836

Incentive-based policies typically assign a shadow price of zero to improvements that exceed the standard(s), while more crude command-and-control policies generally result in "overcontrol" beyond the standards (Oates et al. 1989). Similarly, it is found that 'without trading' and 'with trading' will, due to specific pollution control engineering, bring about 900.9 kg/day and 51.5 kg/day of redundant reduction, respectively, beyond the required reduction if the municipal sources participate in the trading program.

A fair comparison between incentive-based and command-and-control policies necessitates that any additional benefits associated with command-and-control policies be offset against the cost advantages enjoyed by their incentive-based counterparts (Oates et al. 1989). The benefit of additional reduction of 849.4 kg/day (900.9-51.5) could be monetized by the additional control cost, obtained as the product of additional reduction of 849.4 kg/day and the marginal cost of CNY959/kg COD/day. Thus, the net annual benefit arising from trading would be direct pollution reduction cost-savings minus benefit of additional reduction, or CNY1,597,724.

5.0 TOWARDS IMPLEMENTATION

5.1 Other Concerns Important for Implementation

Other concerns that are important for smooth and successful implementation of the TDP system are identified with reference to international experience and local realities, including program design, reporting and monitoring requirements, institutional/ administrative requirements, additional administrative and monitoring costs for trading, alternatives for reallocation of permits, and social implications. To keep the initial system relatively simple, these complex aspects would be addressed in depth at later stages.

5.1.1 Design guidelines

The enthusiasm for tradable permits was, in some cases like Shanghai, so great that policy action and implementation had advanced beyond the understanding of some fundamental design issues. Nevertheless, the program must be carefully designed not only to minimize the administrative and transaction costs imposed on dischargers and regulatory agencies, but also to ensure that trading does not result in degradation of local water quality.

Factors influencing participation must be taken into account in designing the trading program. In particular, the regulatory agency's perceptions of the effects of trading on environmental quality, the likely monopolistic behaviors of the municipal sources that can inhibit trading by industrial dischargers, and the lifespan of permits. Environmental 'hotspots' can be prevented partly by limiting the size of the trading area; another approach is for the regulator to review and approve all trades (NSW EPA, November 1994) so as to keep the effect of trades on water quality under an acceptable level. Monopolistic behavior of municipal sources can be prevented by government intervention or by forming an industrial congregation. Too short a lifespan will be a disincentive to trading. However, if the lifespan of permits is too long, this will restrict flexibility within the trading system and make it more difficult for the regulatory authority to improve water quality (NSW EPA, November 1994). A five-year lifespan of permits seems proper for the Nanpan river.

While designing permits, a requirement that permits be nontransferable on closure of point sources could accelerate improvements in water quality, but would reduce both the incentive to trade and, consequently, the environmental and economic gains from trading.

At large, three points need to be kept in mind when designing the TDP program:

- Try to make provisions as explicit as feasible and minimize the points of administrative intervention;
- Try a pilot program in the aforementioned small area before proceeding to full-blown implementation; and,
- Tailor-make the program for localities, especially the development of market mechanism, role of government and economic background. Cultural and political factors often weaken the effectiveness of the approaches adapted directly from the Western (Barron and Cottrell)

5.1.2 Reallocation of permits

Equilibrium permit allocations and hence aggregate control costs are sensitive to initial permit distributions. The current permit system allocated TMLAs in 1992 according to the actual discharges of the participants. After five years, it is time to determine suitability of that allocation method. The most appropriate load reallocation method needs to be carefully selected, though many load allocation methods seem to be suitable to the trading program: equal percent treatment, equal percent treatment weighted according to locations, effluent standards weighted according to industrial sectors, auctioning, and negotiating. Auction seems to be the best method for preventing corruption.

5.1.3 Compliance monitoring requirements

To ensure that the TRT is met, the regulator must be given the power to review and approve individual trades; the traders are then responsible for reporting trades and monitoring. This helps managers keep track of the ownership of permits and compliance situation. Careful assessment of what to monitor and how to monitor it are essential in building an effective and workable system of environmental law (Barron and Cottrell 1996).

Monitoring systems are more effective and more cost-effective when government monitoring activities are supplemented by well-designed self-monitoring and information from the local community (Barron and Cottrell 1996). Whereas large facilities might be monitored continuously and for a wide range of pollutants, this is unlikely to be feasible (or cost-effective) for many small emission sources (Barron and Cottrell 1996). For smaller sources, the standard-setting and the monitoring program perhaps should be based on process or equipment requirements rather than point-of-discharge measurements (Barron and Cottrell 1996).

5.1.4 Institutional structure and capacity-building

Prior to implementation of the program, one important task is the specification of the relevant structure, responsibility, and mandates of a management agency. The management agency in charge of trading must have adequate statutory authority to allocate permits, reject trades that threaten local water quality, enforce compliance, and enact other permit provisions. The responsibilities of participants in the program must also be defined. Community consultation and education may be required to achieve acceptance of the trading program.

The non-tradable permits of the city-owned industrial dischargers and province- and prefecture-owned dischargers are under the management and supervision of the QMEPB and QPEPB, respectively. They seem to be the most eligible management bodies for the trading program.

5.1.5 Administrative and monitoring costs

Several authors have commented on the potential importance of transaction costs in TDP markets (Hahn and Hester 1989; Tripp and Dudek 1989; US EPA, May 1992). The cost of development and administration of a trading program can be significant, especially for large or otherwise complex waterbodies. The following principal classes of costs are common among most trading programs:

- monitoring and modeling beyond those needed under current policy;
- costs to allocate waste loads for the "with trading" case;
- government transaction costs associated with review and approval of individual trades; and,
- transaction costs, including search and information, and bargaining.

Ten potential trading cases between the existing participants were identified in the trading zone of the upper Nanpan river. Additional costs for the pilot PS/PS TDP program may be low relative to the estimated pollution reduction cost-savings.

5.1.6 Social implications

While economic efficiency is an important ingredient in government policies and water pollution control strategies, equity considerations play an equally important role (NSW EPA, March 1994). In the case of the upper Nanpan river, pollution control has been concentrated on the participants of the permits system. Thus, there is a question of whether it is fair for the permit holders to carry the costs of improving water quality. Nonpoint sources could do this during high-flow seasons, and small industrial dischargers could enjoy the benefits of improved water quality without necessarily paying for the privilege.

5.2 Follow-up Actions

Though eight of the nine necessary conditions for PS/PS TDP are met by the upper Nanpan river, the following must be achieved before the trading system is operational:

- A computer information system to pool information and data on participants and instream water quality changes so as to help trading and management.
- More reliable TMLAs for the trading zone with the one-dimensional water quality model.
- A mechanism to provide the local EPBs with help to reallocate permits.
- A trading rulebook prepared in collaboration with the local EPBs.
- Dissemination of trading rules to the participants.

REFERENCES

Barron, William and Jill Cottrell, report editors. Making Environmental Law in Asia More Effective: participants' report of a regional workshop Hong Kong, March 4-8 1996. Hong Kong: Centre of Urban Planning and Environmental Management

Dean-Jones, Pam head of Regional Programs Unit, NSW EPA. A letter of 2 June 1997

Glover, David 1995. Policy Researchers and Policy Makers: Never the Twain Shall Meet? in Handbook on disseminating Research Results in Environmental Economics. EEPSEA, May

Government of Canada. 1992. Economic Instruments for Environmental Protection (discussion paper). Minister of Supply and Services Canada

Hahn, R.W. and G.L. Hester. 1989. Marketable Permits: Lessons for Theory and Practice. Ecol. Law Quart. 16, 361-406

Kashmanian, R.M., M.K. Podar, M.A. Luttner & R.G. Graff. 1994. The Use and Impact of Intra-Plant Trading in the Iron and Steel Industry. November

National Environmental Protection Agency of China, NEPA. 1993a. Collection of the Best Practical Environmental Protection Technologies (1992). Beijing: China Environmental Sciences Press

National Environmental Protection Agency of China, NEPA. 1993b. Collection of the Best Practical Environmental Protection Technologies (1993). Beijing: China Environmental Sciences Press

National Environmental Protection Agency of China, NEPA. 1994. Collection of the Best Practical Environmental Protection Technologies (1994). Beijing: China Environmental Sciences Press

National Environmental Protection Agency of China, NEPA. 1995. Collection of the Best Practical Environmental Protection Technologies (1995). Beijing: China Environmental Sciences Press

National Environmental Protection Agency of China, NEPA. 1996. Collection of the Best Practical Environmental Protection Technologies (1996). Beijing: China Environmental Sciences Press

NSW Environmental Protection Authority, NSW EPA. March 1994. Using Economic Instruments to Control Pollution in the Hawkesbury-Nepean. Chatswood: Environmental Protection Authority

NSW Environmental Protection Authority, NSW EPA. July 1994. Hunter River Salinity Trading Scheme: Draft Operational Plan. Chatswood: Environmental Protection Authority

NSW Environmental Protection Authority, NSW EPA. November 1994. Point/Nonpoint Source Trading to Reduce Phosphorus Discharges: Literature Review. Chatswood: Environmental Protection Authority

NSW Environmental Protection Authority, NSW EPA. May 1995. Hunter River Salinity Trading Scheme: Guideline and Rulebook. Chatswood: Environmental Protection Authority

Wallace E. Oates, Paul R. Portney and Albert M. McGartland. 1989. The Net Benefits of Incentive-based Regulation: The Case of Environmental Standard-setting in the Real World. Discussion Paper CRM 89-03. March

Office of Leaders Group for Testing Permits System for Water Pollution, OLGTPS. 1993. Study of Pollutant Load Control in the Qujing Catchment of the Nanpan River. Qujing: Government Printer

Patterson, Dale 1990. Tradable Discharge Allocations. Wisconsin Department of Natural Resources

Qujing Prefectural Environmental Monitoring Station, QPEMS. 1993. Environmental Impact Statements of the Innovation Project of Qujing Cigarette Factory. Qujing: QPEMS

Shanghai Design Academy of Municipal Works, SDAMW. 1995. Feasibility Study of the Qujing Municipal Wastewater Treatment Plant. Shanghai: SDAMW

Tao, Wendong 1995. Water Pollution Control and Sustainable Development in the Upper Nanpan River Basin in Yunnan Province, China. Asian Journal of Environmental Management, 3:2, 119-127, November

Tao, Wendong 1996. Review of Tradable Discharge Permits System and Its Prospective Application. Advances in Environmental Science, 4:6, 22-31, December

Township & Village Enterprises Bureau at Agricultural Ministry, TVEBAM. 1991. Pollution Prevention and Control of Paper-making Industry. Beijing: China Environmental Sciences Press

Tripp, J.T.B. and D.J. Dudek. 1989. Institutional Guidelines for Designing Successful Transferable Rights Programs. Yale J. Reg. 6, 369-391

US EPA, Office of Water and Office of Policy, Planning and Evaluation. April 1992. Incentive Analysis for Clean Water Act Reauthorization: Point Source/Nonpoint Source Trading for Nutrient Discharge Reductions. US EPA, Washington DC

US EPA, Office of Water and Office of Policy, Planning and Evaluation. May 1992. The benefits and Feasibility of Effluent Trading Between Point Sources: An Analysis in Support of Clean Water Act Reauthorization (Draft). US EPA, Washington DC

Wang, Hua and David Wheeler. 1996. Pricing Industrial Pollution in China: An Econometric Analysis of the Levy System. PRDEI, March

Xu, Hongde 1996. Policy and Preliminary Practices of Water Pollutant Discharge Trading. Shanghai Environmental Science, 15:3

Yunnan Provincial Design Academy, YPDA. 1990. Design Specification for Wastewater Treatment Plant of Dali Paper Mill. Kunming: YPDA

Yunnan Institute of Environmental Sciences, YIES. 1995. Water Pollution Prevention and Control Planning in the Qujing & Luliang Catchment of the Nanpan River, Report to the Leaders Group for water Pollution Control Planning in the Nanpan River Basin. Kunming: YIES

Yun, Ping 1997. The Pollution Charge System in China: An Economic Incentive? Draft final report to EEPSEA.

Appendix 1. Effluent Characteristics of Participants of Nontrading Permits System

Crucial Pollutants	COD in kg/day			Ammonia Nitrogen in kg/day		
Name of Dischargers	**Actual discharge**	**Permit limit**	**Required reduction**	**Actual discharge**	**Permit limit**	**Required reduction**
Municipal Sources	11331.52	1927.76	9403.76	561.92	224.46	337.76
Industrial Dischargers						
In the Vicinity of Huashan Town						
Xuanwei Phosphorus Plant: Huashan	3.91	3.91		1.57	1.57	
Yunnan Vinylon Factory	1739.00	967.62	771.38			
Zhanyi Fertilizer Plant	1972.26	377.42	1594.84	1293.51	369.76	923.75
In the Vicinity of Xiping Town						
Qujing Municipal Brewery	77.00	29.41	47.59	0.78	0.78	
Qujing Municipal Phosphate Chemical Plant	0.06	0.00	0.06			
Zhanyi Automobile Repairing Factory	5.35	5.35				
Zhanyi Phosphate Fertilizer Plant	23.05	0.00	23.05			
Zhanyi Wool Textile Mill	64.00	80.88				
In the Vicinity of Urban Center						
Guihua Paper Mill	296.38	39.32	257.06			
Kangli Pharmaceutical Plant	0.35	0.01	0.34			
Lanjian Automobile Factory	94.20	94.20				
Qujing Cigarette Factory	857.00	88.85	768.15			
Qujing Highway Transportation Station	41.00	14.15	26.85			
Qujing Municipal Beverage Plant	54.00	7.55	46.45			
Qujing Municipal Food Company: Processing Plant	113.12	3.65	109.47			
Qujing Municipal Leather-Tanning Plant	99.54	29.57	69.97			
Qujing Prefectural Incorporated Meat Plant	46.76	2.98	43.78			
Qujing Prefectural Machinery Plant	0.07	0.07				
Qujing Prefectural Pharmaceutical Plant	270.59	28.96	241.63			
Qujing Tobacco-processing Plant	1.67	1.67				
Qujing Textile Mill	1.07	1.07				
In the Vicinity of Yuezhou Town						
Qujing Chemical Plant	58.61	58.61		94.32	94.32	
Yuezhou Iron and Steel Works	36.89	36.89				
Subsum	5240.14	1872.14	3368.00	1390.18	466.43	923.75
Firms Gone to Bankrupt						
Qujing Dying & Printing Mill	77.06	77.06				
Qujing Municipal Paper Mill	6434.10	550.41	5883.69			
Qujing Silk Plant	56.04	56.04				
The Other Sources	482.47		89.16			
Sum	23754.6	4965.8	18788.8	1952.10	780.05	1261.51

Note: Actual discharge as of 1993; Permit limits are allocations based on the total maximum loads allowable by year 2000 quoted from OLGTPS (1993).

Appendix 2. Pollution Reduction Options and Costs of Potential Participants

	Annual cost, CNY	COD load reduction, /kg/day	Unit cost, CNYkg/day		Annual cost, CNY	COD load reduction, kg/day	Unit cost, CNY/kg/day
GPM1	14,150	22.5	628.9	QMLTP1	17,320	20	866.0
GPM2	18,938	45	420.8	QMLTP2	40,723	85	479.1
GPM3	21,650	80	270.6	QPIMP1	5,245	37.5	139.9
GPM4	63,463	228.8	277.4	QPIMP2	7,160	42	170.5
GPM5	92,220	296.8	310.7	QPIMP3	8,660	44	196.8
LAF1	87,737	40	2193.4	QPPP1	11,740	80	146.8
LAF2	106,250	47	2260.6	QPPP2	30,721	244	125.9
LAF3	183,437	94.2	1947.3	QPPP3	50,073	270.6	185.0
QCF1	71,795	228	314.9	QUC1	2,637,600	3,003	878.3
QCF2	115,987	352	329.5	QUC2	6,769,000	7,308	926.2
QCF3	161,074	404	398.7	QUC3	9,056,600	8,209	1103.3
QCF4	277,205	531	522.0	QUC4	11,344,200	9,110	1245.2
QCF5	357,410	712	502.0	XT1	309,000	352.5	876.6
QCF6	537,350	857	627.0	XT2	788,800	822.5	959.0
QHTS1	8,375	27	310.2	XT3	1,065,300	940	1133.3
QHTS2	14,150	41	345.1	XT4	1,341,900	1057.5	1268.9
QMB1	27,446	50	548.9	ZPFP1	18,294	5.3	3451.7
QMB2	27,765	57	487.1	ZPFP2	170,416	23.05	7393.3
QMB3	42,669	77	554.1	ZWTM0	135,500	67.3	2013.4
QMBP1	14,722	36	408.9	ZWTM1	13,845	5.8	2387.1
QMBP2	19,166	47	407.8	ZWTM2	24,152	13.8	1750.1
QMBP3	24,555	54	454.7	ZWTM3	61,535	36.5	1685.9
QMFC1	8,590	97	88.6				
QMFC2	10,246	104	98.5				
QMFC3	13,058	109.5	119.3				

EEPSEA RESEARCH REPORT SERIES

Economic Benefits of Watershed Protection and Trade-off with Timber Production: A Case Study in Malaysia
Mohd Shahwahid H.O., Awang Noor, A.G., Abdul Rahim N., Zulkifli Y. & Razani U.
May, 1997

An Economic Analysis of Alternative Mangrove Management Strategies in Koh Kong Province, Cambodia
Camille Bann
November, 1997

An Economic Analysis of Tropical Forest Land Use Options, Ratanakiri Province, Cambodia
Camille Bann
November, 1997

Pricing for Groundwater Use of Industries in Metro Manila, Philippines
Maria Corazon M. Ebarvia
November, 1997

Overfishing in the Philippine Marine Fisheries Sector
Danilo C. Israel & Cesar P. Banzon
January, 1998

Understanding Household Demand for Water: The Metro Manila Case
Cristina C. David & Arlene B. Inocencio
January, 1998

The Value of Improved Water Quality for Recreation in East Lake, Wuhan, China
Du Yaping
May 1998

Economy and Environment Program for Southeast Asia